RTR Use in Asphalt and Concrete

Arizona Pavements/Materials Conference
Arizona State University
Tempe, AZ
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Doug Carlson
VP Asphalt Products
Rubberized Asphalt is Triple Green

Recycled Materials Have To Perform
Better, Save Money, and be Sustainable
End of Life Tire Market

About 300 Million End of Life Tires Generated Each Year

About One Per Person/Year

About 10% Growth in RTR Asphalt/Year

U.S. Scrap Tire Market Trends
2005 - 2009

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Dramatic Increase in Cost

Crude Oil, Gas and Asphalt Costs

Relative Cost of Rubber
The Cost of Newly Manufactured Modifiers is Tied to the Current Price of Oil

Regular and Modified Asphalt Costs 2008, crude oil hit $147 per barrel July

Source: Peter Wu, GA DOT
Evaluation of Ground Tire Rubber in Asphalt Binders and Mixtures
## NCAT PG Results

<table>
<thead>
<tr>
<th>Rubber Product</th>
<th>Dosage Rate, %</th>
<th>True Grade</th>
<th>Performance Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30 Liberty</td>
<td>10%</td>
<td>80.7 – 23.6</td>
<td>76 – 22</td>
</tr>
<tr>
<td>-20 Liberty</td>
<td>10%</td>
<td>83.1 – 24.6</td>
<td>82 – 22</td>
</tr>
<tr>
<td>-20 Liberty</td>
<td>15%</td>
<td>87.9 – 21.3</td>
<td>82 – 16</td>
</tr>
<tr>
<td>Crackermill</td>
<td>10%</td>
<td>82.8 – 23.1</td>
<td>82 – 22</td>
</tr>
<tr>
<td>Cryo-Hammer</td>
<td>10%</td>
<td>82.2 – 23.2</td>
<td>82 – 22</td>
</tr>
<tr>
<td>Cryo-Hammer</td>
<td>15%</td>
<td>86.7 – 19.3</td>
<td>82 – 16</td>
</tr>
<tr>
<td>-30 Liberty Fines</td>
<td>10%</td>
<td>79.8 – 20.4</td>
<td>76 – 16</td>
</tr>
<tr>
<td>-16 Powderizers (1mm gap)</td>
<td>10%</td>
<td>76.3 – 21.8</td>
<td>76 – 16</td>
</tr>
<tr>
<td>-16 Powderizers (2 mm gap)</td>
<td>10%</td>
<td>84.7 – 21.8</td>
<td>82 – 16</td>
</tr>
<tr>
<td>Virgin Binder</td>
<td></td>
<td>69.2 – 24.7</td>
<td>67 - 22</td>
</tr>
</tbody>
</table>
• About 3 x RTR loading is needed compared to SBS for similar properties.
  – Example: 3% SBS content = 9% RTR Content

• Suppose SBS costs $2.00/Pound and RTR Costs $0.50/Pound
  – Example:
    – 3 Pounds SBS = $6.00,
    – 9 Pounds RTR = $4.50

• Project with 1000 Tons of Modified of Binder
  – SBS at 3% = 30 Tons Needed @ $2.00 = $120,000
  – RTR at 9% = 90 Tons Needed @ $0.50 = $90,000
• M320 – PG Asphalts, allow modifiers, particulate 600 microns in size (30 mesh)
• T44 – Solubility Test
• MP19 – PG Asphalt using MSCR
• T315 – The DSR, 2 mm gap
• In 2008, a substantial price spike in asphalt costs struck the paving industry nationwide.
• The use of Reclaimed Asphalt Pavement and Recycled Asphalt Shingles increased to solve the problem of high asphalt costs.
• The performance of RAP and RAS is measured through mix tests, not the liquid binder.
• This is a significant opportunity for Recycled Tire Rubber, as long as it costs less than asphalt and does not increase the liquid requirement (add cost) at the asphalt mix plant.
Mix Performance Tests Are More Common with the Use of RAP and RAS
New “Dry Process”

- Research Published at the LTRC, (Sam Cooper and Louay Mohammad), work underway at several Universities and within suppliers to the asphalt industry.
- Rubber particles pre-treated with useful liquids before packaging, or co-packaged with low melt processing aids or powders before delivery to mix plant.
- GA DOT using a co-packaged “Plant Mix” rubber.
Test Section in Hawkinsville, GA on SR 26
RTR Blended with Reactive Type of Polymer
Blended RTR Being Added To Plant at RAP Collar
<table>
<thead>
<tr>
<th>Mixture</th>
<th>Control 58-28</th>
<th>Control &amp; %10 Wet Processed Rubber</th>
<th>Control &amp; %10 Pre-Treated Rubber</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Binder content</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>Virgin Binder Added, %</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>Air Voids, %</td>
<td>4.3</td>
<td>4.7</td>
<td>4.8</td>
<td>4-6</td>
</tr>
<tr>
<td>Voids in Mineral Aggregate %</td>
<td>19.7</td>
<td>21</td>
<td>20.5</td>
<td>18 min</td>
</tr>
<tr>
<td>Voids Filled with Asphalt, %</td>
<td>78.2</td>
<td>77.6</td>
<td>76.8</td>
<td>65-78</td>
</tr>
<tr>
<td>Binder Absorbed, %</td>
<td>0.62</td>
<td>0.16</td>
<td>0.48</td>
<td>-</td>
</tr>
<tr>
<td>Dust to Binder Ratio</td>
<td>0.67</td>
<td>0.63</td>
<td>0.62</td>
<td>-</td>
</tr>
<tr>
<td>Test Result</td>
<td>Control 58-28</td>
<td>Control + 10% Wet Process Rubber</td>
<td>Control + 10% Dry GTR Mix</td>
<td>Control + 10% Pre-Treated Rubber</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------</td>
<td>----------------------------------</td>
<td>---------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Average Overlay Test (OT) Cycles to Failure</td>
<td>1466</td>
<td>381</td>
<td>230</td>
<td>1645</td>
</tr>
</tbody>
</table>
Emerging Technologies

PELLETIZED ASPHALT-RUBBER

ASPHALTITE COVERING

HYDRATED LIME
PelletPAVE™

Providing Asphalt-Rubber Technology for Pavement Maintenance

Cost Effective and Convenient
Most Rubber Projects are still performing and do not need to be recycled.

Over eight agencies have reported successful recycling projects at 15% or greater rubber Reclaimed Asphalt Pavement.
RTR Has Successful Performance With Warm Mix Rubber friction course on I-78 in New Jersey.

Rubberized asphalt overlay on I-295 in Massachusetts.
<table>
<thead>
<tr>
<th></th>
<th>Dense Grade</th>
<th>GAP (SMA) Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coarse Grind</td>
<td>Fine Grind</td>
</tr>
<tr>
<td>Binder Content</td>
<td>5.0%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Rubber Content</td>
<td>20.0%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Stones</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Asphalt</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>Polymer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Blending</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total Materials per Ton of Mix</td>
<td><strong>53</strong></td>
<td><strong>72</strong></td>
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</table>
### Ride Quality / Roughness

#### IRI (in/mi) Comparison

<table>
<thead>
<tr>
<th>LANE</th>
<th>IRI (in/mi)</th>
<th>PCCP</th>
<th>AR-ACFC</th>
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</thead>
<tbody>
<tr>
<td>I010EHOV</td>
<td>96.34</td>
<td>43.57</td>
<td></td>
</tr>
<tr>
<td>I010ELN1</td>
<td>123.20</td>
<td>59.03</td>
<td></td>
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<tr>
<td>I010ELN2</td>
<td>104.29</td>
<td>48.81</td>
<td></td>
</tr>
<tr>
<td>I010ELN3</td>
<td>111.87</td>
<td>47.80</td>
<td></td>
</tr>
<tr>
<td>I010ELN4</td>
<td>115.30</td>
<td>52.91</td>
<td></td>
</tr>
<tr>
<td>I010WHOV</td>
<td>85.44</td>
<td>32.51</td>
<td></td>
</tr>
<tr>
<td>I010WLN1</td>
<td>87.94</td>
<td>37.79</td>
<td></td>
</tr>
<tr>
<td>I010WLN2</td>
<td>85.40</td>
<td>46.92</td>
<td></td>
</tr>
<tr>
<td>I010WLN3</td>
<td>96.83</td>
<td>46.11</td>
<td></td>
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<tr>
<td>I010WLN4</td>
<td>97.75</td>
<td>36.81</td>
<td></td>
</tr>
</tbody>
</table>

#### Profilometer Test-Deck Park Tunnel I010 East HOV Comparison

**IRI (in/mi) LANE PCCP AR**

- I010EHOV: 96.34, 43.57
- I010ELN1: 123.20, 59.03
- I010ELN2: 104.29, 48.81
- I010ELN3: 111.87, 47.80
- I010ELN4: 115.30, 52.91
- I010WHOV: 85.44, 32.51
- I010WLN1: 87.94, 37.79
- I010WLN2: 85.40, 46.92
- I010WLN3: 96.83, 46.11
- I010WLN4: 97.75, 36.81

**Distance every 100ft**

**Profilometer Test-Deck Park Tunnel I010 East HOV Comparison**

**PCCP to AR**
Rubberized Asphalt Performs Better, Saves Money, and is Sustainable
• Rubber crumbs may function as a distribution of mini expansion / control joints inside the concrete.
• Thus, the crumb rubber concrete may exhibit good characteristics in controlling crack initiation and propagation.
Field Experiments

- Feb 1999, ASU sidewalk, 40 lbs.
- June 2001, ASU wheel chair ramp, 20 lbs.
- May 2001, ADOT parking lot, 60 lbs.
- March 2002, residential patio foundation in Mesa AZ, 20 cr/cy.
- April 2002, NAU campus (cold climate), 60 lbs.
- March 2003, residential sidewalk in Scottsdale, AZ, 25 lbs.
At Hanson’s Aggregates in Phoenix, AZ:
- test slab 5 x 25 feet and 2 inches thick
- 400 lbs of cr/cy, 25% of the concrete mix by volume
- was placed without any joints
- slab serves as a truck parking facility
- no cracks have been observed as of 2006
- provided useful experience about mixing, hauling, pumping, placing, finishing, and curing of crumb rubber concrete.
• January 2003: experimental test slabs
  – 2x4 ft in size
  – thickness 2 - 3 inches
  – 50 >= 300 cr/cy.

• Tests included: compressive strength,
  flexural strength, indirect tensile strength,
  and thermal coefficient of expansion.
Mix Characteristics

Rubber Content, lbs/cy vs. Compressive Strength (psi)
- 3-day Strength
- 7-day Strength
- 28-day Strength

Unit Weight (lbs/ft³) vs. Rubber Content (lbs/cy)

Air % vs. Rubber Content (lbs/cy)
- Air % C138

Slump (in) vs. Rubber Content (lbs/cy)
Tennis Court Trial Mixes

50 - 100 - 150 lbs
Initial Test Results

Test Parameter

- Strain (%)
- Time to failure (sec)
- Tensile Strength (KN)

Results

- 400 lbs Crumb Rubber / CY
- No Crumb Rubber

- Strain (%): 0.56, 0.31
- Time to failure (sec): 2.78, 0.83
- Tensile Strength (KN): 2.39, 5.30
• Evaluate CRC using fundamental tests.
• Build and monitor field demonstration test sections, and evaluate the long term performance and benefits of using crumb rubber concrete materials.
• Share findings with state governments, associations, industry and private sector
Two UTW pavement test sections
Laboratory Tests

- Compressive Strength
- Three Point Bending
- Panel Test
- Shrinkage
- Coefficient of Thermal Expansion
<table>
<thead>
<tr>
<th>MIX. ID</th>
<th>Age Days</th>
<th>Average Compressive Strength psi</th>
<th>Peak Axial Strain in/in (10^{-3})</th>
<th>Axial Modulus of Elasticity psi (10^6)</th>
<th>Poisson's Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 lbs per Cyd (Const.)</td>
<td>7</td>
<td>822</td>
<td>9.65</td>
<td>0.15</td>
<td>NA</td>
</tr>
<tr>
<td>300 lbs per Cyd (Const.)</td>
<td>28</td>
<td>1080</td>
<td>10.32</td>
<td>0.16</td>
<td>NA</td>
</tr>
<tr>
<td>400 lbs per Cyd</td>
<td>14</td>
<td>546</td>
<td>6.50</td>
<td>0.11</td>
<td>NA</td>
</tr>
<tr>
<td>TW_CTR</td>
<td>14</td>
<td>5363</td>
<td>1.05</td>
<td>5.30</td>
<td>0.25</td>
</tr>
<tr>
<td>TW_CTR</td>
<td>28</td>
<td>5975</td>
<td>0.52</td>
<td>6.10</td>
<td>0.26</td>
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<tr>
<td>TW_CR 50</td>
<td>14</td>
<td>3704</td>
<td>1.29</td>
<td>3.14</td>
<td>0.25</td>
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<tr>
<td>TW_CR 50</td>
<td>28</td>
<td>4430</td>
<td>0.73</td>
<td>5.63</td>
<td>0.22</td>
</tr>
</tbody>
</table>
### Parameters Measured in Flexural Test

- Flexural load (lbs)
- Deflection: Measured by the LVDT (in)
- Crack Mouth Opening Displacement (CMOD): Measured by the actuator (in)

<table>
<thead>
<tr>
<th>MIX. ID</th>
<th>Age Days</th>
<th>Flexural Load lbs</th>
<th>CMOD in (10⁻³)</th>
<th>Flexural Strength (psi)</th>
<th>Toughness psi x in</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 lbs per Cyd (Const.)</td>
<td>28</td>
<td>481</td>
<td>1.85</td>
<td>157</td>
<td>9.4</td>
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<tr>
<td>TW_CTR</td>
<td>14</td>
<td>1049</td>
<td>0.97</td>
<td>341</td>
<td>8.4</td>
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<tr>
<td>TW_CTR</td>
<td>28</td>
<td>1188</td>
<td>1.30</td>
<td>387</td>
<td>10.3</td>
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<tr>
<td>TW_CR 50</td>
<td>14</td>
<td>807</td>
<td>1.67</td>
<td>263</td>
<td>7.6</td>
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<tr>
<td>TW_CR 50</td>
<td>28</td>
<td>932</td>
<td>1.39</td>
<td>303</td>
<td>9.5</td>
</tr>
</tbody>
</table>
300 lbs / C.Y. Tennis Court Mix
The distresses are a function of the CTE values. Lower values of CTE in the mix results in less faulting, lower percentage of cracking.
Conclusions

• Advantage of unit weight reduction with increased crumb rubber content.
• Entrapped air and very high rubber content contribute to compressive strength reduction. However, higher strength values are achievable depending on design requirements.
• Similarly, flexural strength reduction may be compensated for by higher ductility and comparable toughness.
• Higher tensile strain at failure for CRC mixes is indicative of higher energy absorbent mixes and less prone to shatter.
• CTE results indicated that CRC mixes are more resistant to thermal changes.
Final Thoughts

• Performance monitoring is needed to validate durability and mix characteristics.
• There are advantages and disadvantages for the use of CR PCC, careful consideration should be given for each design case.
• Improved mixture characteristics are possible through mix optimization. Watch for entrapped air.
• Crumb rubber content is also specific for mix usage or application.